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ABSTRACT

This paper discusses some of the significant issues that school districts, superintendents, principals, board members, and faculty will have to face in the acquisition and implementation of educational hardware and software. Strengths and weaknesses of various computer configurations are presented and it is suggested that the use of professional systems is probably the best choice for school districts if they wish computers to have a serious instructional impact. It is also suggested that if school districts are not careful in their planning, purchasing, and implementation strategies, there may be a backlash against computers before their real advantages and strengths are understood. It is pointed out that behind the choice of the hardware systems and vendors is a deeper issue that educators must understand, i.e., the advent of computer technology will allow for extraordinary contributions to the advancement of education since computers will help improve the educational delivery system. A large portion of the discussion focuses on the concept of delivery systems and examples from the experience of the WICAT Education Institute's research school--the Waterford School--illustrate the use of a professional system. Current research is also discussed, particularly research on testing, which will allow new kinds of contributions to be made to the learning and testing processes. The paper concludes with short discussions of several important issues regarding instructional computing that school districts should consider. (JB)

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SOME OF THE CRITICAL ISSUES IN INTRODUCING COMPUTER TECHNOLOGY INTO SCHOOLS

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Preface

This paper discusses some of the significant issues that school districts, superintendents, principals, board members, and faculty will have to face in the acquisition and implementation of educational hardware and software. It discusses the strengths and weaknesses of various approaches and suggests that the use of professional systems is probably the best approach for school districts to follow if their motive is to have computers offer a serious instructional impact. If on the other hand, the districts are interested primarily in teaching literacy and computer programming, then they probably are better off with personal computers on either a standalone or networked basis.

The paper also suggests that if school districts are not careful in their planning, purchasing, and implementation strategies, that there may be an inevitable backlash against computers before their real advantages and strengths are understood. An important concept that is elaborated is that the introduction of computers should be education driven, and not market driven. Too many districts are spending their precious resources on acquiring inexpensive micros sold to them by corporations who want their revenues but really do not have the educational software, or even the appropriate hardware for serious instructional usage. The misinformation that is confusing the unsophisticated districts is not a good omen for the successful introduction of educational technology. In fact, the really responsible and well-trained experts who understand the field are deeply concerned that this misinformation, with the attendant purchasing policies, will lead to student, faculty, parental, and school board antagonism or apathy just at the time when computers can make a genuine contribution to education if there is a careful planning, purchasing, and implementation cycle.

Schools have learned that standalone microprocessors are of little help in improving instruction, and now they are being led into a new round of purchasing where these standalone microprocessors are being fed into file servers with the promise that somehow the file server will improve the problem. When schools learn that this approach is not very much of an improvement, then there is the danger of the backlash against all computers.

In addition to the danger of the backlash, there is a second problem that schools must face. If they fail to understand the full potential of what computers can do, they may be sold an approach by salesmen that meets their expectations but seriously diminishes the potential contribution to their students. In this case, the schools have failed to do their homework and have not come to terms wit the fundamental potential of the new educational delivery system which incorporates the computer as a professional partner in helping to teach all subjects.

Behind the choice of the hardware systems and vendors is a deeper issue that educators must come to understand: the advent of computer technology will allow for an extraordinary contribution to improving education because computers will help us change and improve the <u>educational delivery system</u>. The paper discusses in some length the concept of the educational delivery system, and how it will change over the next decade. It tries to illuminate the difference between this educational technology and all the other technologies that have gone on before. While clarifying the extraordinary

contributions the new delivery system will offer, and elaborating on these in some detail, it also tries to give a balanced view of how important the traditions of the current delivery system are and how the new and old delivery systems will mesh in the future.

Examples are drawn from the experience of the WICAT Education Institute's research school, the Waterford School. The paper restates the importance of the teacher and tries to clarify what Waterford has taught us about the new role of the teacher, as well as examples of how the school and classroom will be affected by the new delivery system.

There are also some discussions of what the newer research is finding, particularly in the testing field, which will allow entirely new kinds of contributions to be made to the learning and testing processes. The paper concludes with a few short sections discussing some of the issues that should be clarified but are not always taken into account by school districts.

Background

Although schools are just now beginning to become involved in the introduction of microcomputers, there is a vast residue of knowledge that has been culled from significant experimentation in the field of computer education for the past 20 years. Schools who are planning to make a commitment to the use of computers should be aware of some of these lessons during their planning and implementation phases. Furthermore, there are some new areas of research being done at WICAT that suggest that with proper planning and purchasing policies, schools will find that computers will be able to offer unexpected benefits to the students, faculty and administration.

In order to take advantage of the lessons learned over the past two decades, and also to prepare for the new contributions that are currently in the research stage, school districts will have to make the correct hardware choices to ensure that they do not inadvertently limit the potential contribution of computers to their students' education. The current approach being followed by most schools, (the acquisition of a few inexpensive micros whenever surplus dollars can be found), is not necessarily the best one for their students unless they intend to restrict the use of computers to computer literacy, programming and limited drill and practice exercises.

A clear alternative to the gradual acquisition of microcomputers is the purchase of professional systems that have been designed with all of the technical features required for running ideal educational software in a school setting. Professional systems are slightly more expensive and have to be purchased with clusters of terminals, but they have the potential to make a far greater educational contribution to the students than the popular microcomputers. The purpose of this paper is to clarify the potential of various approaches in introducing computers to schools.

A Note on WICAT

WICAT represents two separate and distinct organizations. One is a non-profit organization currently called The WICAT Education Institute. The WICAT

Education Institute was founded as a non-profit organization in 1976, and its mission is to help public schools by doing research in how to use computers in a school setting. Toward this end it is running a research school. The Institute is also doing extensive research in curriculum and testing, with the goal again being to help public schools utilize the full educational potential of the computer.

Four years after its founding, the non-profit transferred its commercial assets out to a new company called WICAT Systems. The non-profit did this because some of its research was beginning to have commercial applications, and also because it was unable to gain enough financial support as a non-profit institute to conduct serious research. Recognizing that a higher level of capital would be required to keep the research going at a significant level, the trustees of the non-profit decided that in forming WICAT Systems, the non-profit, through retaining 50 percent of the common stock of the new company, could hopefully achieve financial independence by owning a good portion of the new company. In order to have a clear separation of the two entities, a separate board of directors was formed for the profit-making entity.

On October 1, 1980, four years after the beginning of the non-profit institute, the profit-making corporation was formed. Then, over a 2 1/2 year span, WICAT Systems raised approximately $100 million to pursue business interests in three areas:

- Educational hardware and software
- Training hardware and software for industry and the government
- The manufacturing of general purpose hardware systems.

After the dilution of the stock through outside investor participation, the non-profit still retains approximately 20 percent of the common stock of WICAT Systems. The non-profit's research school, The Waterford School, opened in September of 1981. Currently, it has classes from Kindergarten through the 10th grade and is adding a section a year until it is a K-12 school. The school has section sizes approximating those of the public schools (25-28 students per class). It differs from a typical public school because of its research emphasis in learning how to use computers in a school setting. Currently there is one computer terminal for every three students and a great deal of research is being done in such issues as:

- How many minutes a day student should work on a terminal
- Where the terminals should be located
- How the faculty should be trained
- What the new role of the teacher will be in relation to the computer
- How the faculty members will relate their standard classroom curriculum to the computer curriculum
- What instructional techniques seem to work best
- What the role of the computer is in testing
- What the types of information are that the teachers want in their computer management reports
- What the best administrative approach is to managing the computer center
- What implementation strategies should be used to assure smooth adoption of the equipment
- How [illegible] on the computer affects the student's learning

The school has learned useful lessons which will be reported through a series of research reports to public schools. One of the comforting things that the school has learned is that once the materials are available and working naturally, the faculty and students are pleased with the help that the new technology offers; and faculty or student resistance, once considered a potential obstacle, is not an issue. The Waterford research further suggests that schools will be able to follow much of their current classroom structure while releasing their students for anywhere from 20 minutes to 1 1/2 hours a day to computer centers where the additional instruction, enrichment, and testing will take place.

The other research emphasis of the Institute is in the use of computers for testing. It is becoming quite clear that well-programmed computers designed for testing that utilize the latest testing techniques now being developed will be able to offer a new range of significant benefits to children, faculty, and parents. From a practical point of view this means that the poorest child in the most remote setting will soon have available the type of testing and information that hitherto was available to only the wealthiest students. In fact, since the computers will add some new measurement techniques to computer testing, the poorer students will have even better tests available than their wealthier counterparts do now.

This testing will lead to a whole new field involving the development of a personal learner profile on each student. This profile will help establish how the student learns best as a learner, what his hidden talents might be, where he stands in his pursuit of basic competencies, whether or not he has any learning disabilities, and how he might best learn because of his unique learner profile.

Inevitably, Computer Adaptive Testing will then lead to the new field of Computer Adaptive Learning where the instructional materials will be automatically presented in a manner fitting the strengths of the individual learner profile. It will take a number of years to finish the research and learn how to release the information without falsely stereotyping students, but clearly we will see the democratization of testing and instruction at the most sophisticated and effective levels as a result of the new technology.

What is not understood about the importance of this new approach is that for the first time we can be certain that children will be given access to information about themselves and their potential that far exceeds what most schools and communities can offer at the present time. This information will be invaluable because of future societal trends. One government study estimated that 70 percent of the incoming Kindergarten class will work at jobs (as adults) that have not yet been invented. Other studies are beginning to estimate how many times in a lifetime a career might have to be changed. The standard estimate now is four. Thus any help in teaching students about their latent abilities and interests that could be applicable to the broad new career patterns emerging should be very helpful. Similarly, the data will be useful to faculty members in helping them shape their teaching strategies and directing the student's efforts.

The profit-making company, WICAT Systems, has spent approximately $25 million developing educational software and has designed special hardware, called professional systems, for school usage. WICAT has collected over three dozen

Ph.D's and has between 150 and 200 people working on the development of new courses in most curriculum areas for grades K-12. WICAT believes that there will be two types of systems being used in schools and homes: the small microcomputers, and the newer type of system called the professional system which is built exclusively for educational usage in the schools. The educational software WICAT is developing runs on both the professional system and the personal computers. WICAT believes that families who are using the computer software at home would prefer that the materials be related to those on the professional systems in the school. For this reason it has its development teams develop both professional and personal computer software simultaneously, with the personal computer version being a subset of the professional system.

The Most Common Misunderstanding About Computers

Perhaps the most misunderstood aspect of the use of computers is that they are being viewed as just another new technology that schools will have to master because the computer will play an important role in the future of our country. Implicit in this approach is the belief that students should be trained on computers to gain computer literacy and to learn how to program on them. Given this belief, the gradual acquisition of small micros is a very sensible approach.

But most schools are making a serious error in not understanding that computers are also capable of offering a new delivery system which will have extraordinary implications for teaching all disciplines far more effectively. Those schools that recognize the educational delivery system will be changing and plan accordingly will offer their constituencies far more value than those who fail to recognize the fundamental changes coming with the new delivery systems.

The Concept of a Delivery System

Whenever a delivery system changes in society, extraordinary opportunities become available. For example, in the communications industry, the fastest way a message could be conveyed in the 1860's was through the use of the horse. Men using the Pony Express were restricted to an availability of one horse power in aiding the rider to get the message from the east to the west coast. In the 1860's the delivery system changed when the telegraph was hooked up which harnessed electricity running at half the speed of light for its new delivery system technology. Once the telegraph was hooked up, the new delivery system could deliver a message from New York to San Francisco faster than a rider could get on his horse and get the horse to take its first step heading west. As a result, the Pony Express business closed five days after the introduction of the commercial telegraph.

The same thing happened in transportation when men transitioned from the use of the horse to the train, then the car, and finally jet aircraft. Each new delivery system introduces a new technology which can do exponentially more work than the previous technology. Thus a horse averages one horse power, a car 400 horsepower, and a jet 40,000 horsepower.

The Problem of a Mature Delivery System

Every delivery system can offer a certain amount of useful work when it is being directed by reasonably well-trained humans. At some point, however, the delivery system becomes mature and trying to get more work out of it is of little use. In fact, pouring more money into it when it is mature does not improve it. Using a silly analogy, but one that will help clarify the concept, if today we had only the horse to help us in transportation, and we decided to have a national initiative to improve the horse, we would probably have something like the following scenario. The National Science Foundation would give $10 billion in grants to improve the technology of the horse. Out of this would come a new horseshoe for the horse using titanium. The National Institute of Health would allocate another $10 billion for research on how to improve the nutritional and feeding practices for horses. The Office of Education, in a separate initiative, would spend $10 billion in learning how to educate riders and trainers to use the horse more efficiently. Finally, NASA would be called upon to work on aerodynamically streamlining the horse and riders to minimize friction. They might discover some trick of controlling the horse's mane more efficiently to reduce drag.

But after spending $40 or $50 billion, scientists and scholars would still have the same general delivery system using the horse, and the output of the horse would still probably not be much better than 1 horsepower. They might get up to 1.2 horsepower but this would be of little help. The important point is that pouring money into a mature delivery system is a waste, and no amount of honest concern, commitment, and investment can change this fact.

The Educational Delivery System

The educational delivery system has remained essentially unchanged for about 500 years. The last significant change in the delivery system came from an earlier technology, the printing press. As always happens when delivery systems change, the printing press offered a significant increase in the amount of work that a teacher could do by making his information available over distance and time. In other words, students could learn who were geographically separated from the teachers and even from teachers who were no longer living. Over the past 500 years we have spent a great deal of money improving the delivery system that uses teachers and books, but now that delivery system is relatively mature. <u>The key indicator that a delivery system has become mature is that when more money is invested, there is little or no improvement</u>. Thus in the case of the horse, pouring more money in would be of little help.

We seem to have evidence that the educational delivery system has matured in our country. Between 1950 and 1975 the percentage of the gross national product spent on education rose from 3.4 to 7.4 percent, an increase of 118 percent. During this period, measurable benefits from this investment appear to be negligible. Generally speaking, student scores went down. In other words, having more than doubled the expenditure for the educational delivery system there was no improvement. This suggests that the educational delivery system is mature.

At the same time, our nation is beginning to realize that the educational delivery system is not meeting the national goals required of it. One report concludes that we have a "nation at risk" because the educational delivery system is too ineffective.

Clearly the reports have begun to pinpoint the problems of educational delivery system, especially in the problem of national productivity. For example, if America continues to allow 42 percent of its 17-year old black students to be functionally illiterate, then the nation will be put at risk because its national productivity will be severely damaged. The nation will have to provide support for individuals and families that cannot be gainfully employed, and this means that the cost of manufactured goods and services for that country or nation will be much higher than a nation where more workers can be effectively used. As jobs increasingly require more education and the ability to change careers, the educational delivery system becomes an increasingly important component of the success of the nation.

The normal reaction when something is not going well and there is a perceived national need is to initiate heavy funding patterns to improve the problem. If WICAT is correct, however, putting more money into a mature delivery system will not be helpful, either at a national, state, or district level. In one sense the lack of support for the schools over the past few years has probably been a subconscious response by the voting public recognizing that heavy expenditures have not improved the educational delivery system.

Because of the dawning realization of the seriousness of our national educational problems, there will be a renewal of heavy funding patterns with more accountability required from legislators, particularly in the basic skills areas. Undoubtedly this new tightening up of accountability, coupled with improved funding and an emphasis on tougher curriculum will improve the results somewhat. But in the end, even with the best intentions, society will still end up facing the same general problem: the educational delivery system has matured and simply pouring a great deal more money into it will not help significantly.

Understanding some of the natural limits of the educational delivery system helps clarify why the educational problems will not be able to be solved by simply investing more money in the current system. The symptoms of the current educational delivery system problem follow from the natural work limit that has been reached by the teachers given the tools they have to support them in their work. The limit can best be expressed in discussing how much individual instruction a student can have in a normal school setting. Two large research studies have indicated that at best a student can have between 10 and 20 seconds of individual instruction per hour in a school setting. This comes out to 1-2 minutes a day, a half a day to a full day a year, and 6 1/2 days to 13 days over the entire elementary and secondary career of the student. If the delivery system is to improve, then significantly greater individualization will become necessary.

Another example that clarifies the limits of the current educational delivery system is the dilemma the teacher faces in teaching the average class where he finds himself lecturing to a class whose individual differences make a mockery of any attempt on his part to teach to an appropriate level for the whole class. In fact, as a class advances each year, the problem gets worse. A

good rule of thumb about a typical elementary school is that there are as many years of difference in student performance in any class as the year of that class. For example, in the second grade there are probably two years of ability difference. In the fifth grade it has expanded to five years of ability difference, and by the 8th grade, to 8 years. For example, in reading, one student might be reading at a 4th grade level in the 8th grade and another at the 12th grade level. The obvious delivery system problem is that the teacher has to talk to a group with a significant ability spread, and hence most of the commentary must be pitched at some middle level which helps as many of the students as possible but cannot possibly be appropriate for everyone.

Somehow we have an eternal hope that the teacher will be able to work with the slower students, or even the brightest students, on an individual basis that will help them achieve their full potential. Nothing could be further from the truth.

The obvious response is that maybe we can afford to add more teachers or additional paraprofessionals per section, but doubling the few seconds per hour is still not going to handle the full requirement for individual instruction. Furthermore the additional salary money is more apt to be used for bringing salaries up to better living standards for the teachers rather than adding a whole new range of paraprofessionals or teachers.

In addition, one study in the Portland School District in Oregon, showed that the addition of paraprofessionals to the classroom did not produce a significant improvement.

Improving Educational Productivity

Businessmen are sensitive to the importance of discussing productivity. After five centuries of working with teachers, we have learned how to encourage them to be as productive as possible. The original uses of technology over the past 500 years have been to try to make the teacher more productive by replicating him on television, radio, videotape, movies, and slide and audio tapes. The assumption has been that the teacher is the expensive component and, therefore, improving his productivity is the essential issue.

In fact, the real expense and where we need the improvement in productivity is in the learner. When a learner cannot be working on individual instruction at a level appropriate to his immediate needs, he may sit passively while the teacher gives him inappropriate information. Since learners have never been paid salaries, there has been a tendency not to count them as a cost item. In fact, when they emerge ill-trained, they can cost the society enormous dollar amounts over a lifetime. Therefore the new emphasis will have to be on making the learner productive.

The only technology which can do this is the computer because unlike the other technologies, it forces the learner to be active rather than allowing him to be passive. And when it forces him to be active, it has enough intelligence in its programs to branch appropriately to responses that continue to help the learner at the level that he needs at that time.

The Promise of the New Delivery System

Through the proper addition of the new technology, schools can make a fundamental change to the current educational delivery system which will be of great service to the students, the faculty, the parents and the nation. When this is understood by educational leaders, we will see a resurgence of hope about our education that we have not felt as a nation since the 1960's. The next 15 years will be an exciting time as computers are introduced into the essential fabric of the delivery system to help the teacher better teach all subjects rather than just using the computers to teach a new computer discipline. This message of hope is exciting because it will combine the natural proclivities of the American culture to develop great new technologies with its inherent belief in democracy. This will produce the democratization or equalization of educational opportunity. Stated plainly, when this new delivery system is in place, we will be able to guarantee every child an equal educational opportunity equivalent to the finest that the culture now offers to only the wealthiest child. In offering the additional individualization with carefully developed programs, the students will have access to personal tutorials carefully crafted by some of the finest educators in the country. Or put another way, the poorest child will have the opportunity to go to the finest school.

We badly need this sense of hope in education because it is so important that our country sustain its belief in its public school system lest we split into a two-tiered society.

With this message of hope, however, there are some necessary cautions that must be acknowledged lest the opportunities be lost through careless enthusiasms or misunderstandings. Some of these are:

(1) Although the role of the teacher may change slightly as technology is added to the delivery system, the teacher will always occupy the central role in the training of our young. Children identify with, model on, are motivated by, and desperately need the attention and commitment of the finest faculty members that we can provide. Computers will never replace teachers, nor should they be considered an excuse to dramatically enlarge class size.

(2) It is in the nature of delivery systems that they are binary. This means that they either work or do not, but until all the elements required for the new delivery system are in place, there will be no essential change. Once all the pieces are in position, then the change can move forward with great rapidity. For example, in order to have the new railway transportation delivery system become effective, we had to lay the track throughout the country. Similarly, in the introduction of the automobile, we had to build roads, and produce a support structure with gas stations, repair facilities, etc.

In the case of introducing computers as a new delivery system, we need to see a number of things happen:

- Significant serious courseware will have to be developed at the cost of approximately $1 million a course. An initial investment of at least $30 million will have to be focused on the elementary and

secondary level for any given set of hardware, and then an additional $20 million will be required to round out the general curriculum circuitry on behalf of the students. This is currently expressed by having a computer run programs at so many thousands or millions of instructions per second. In order to have this enormous work bonus from the new delivery system used effectively, a new kind of developer has to emerge that understands both classical curriculum and the new machines. Generally speaking, most of the product being marketed for educational purposes has from $5,000 to $25,000 spent on it. This means that schools are being offered bits and pieces written in a rather careless approach that will be of very little serious instructional value to the students.

- In order to have the curriculum be effective, it will require extensive management programs to give faculty reports on the status of their students. Research is indicating that these reports are the key to harnessing the teachers interest and commitment in working with the programs. This new "microscope" gives them invaluable information on the status of their students in everything from basic skills to complex reasoning skills.

- This curriculum will also have to have significant "help" and "tutorial" features. In the early attempts of CAI, (Computer Assisted Instruction) students were given problems and told whether they were right or wrong. Then after they missed it twice, they would be given the answer. While in some cases getting the answer might clarify the problem, in many cases the students did not understand what they did wrong and hence had to wait to talk to the teacher to find out. This delay puts the student back into the old delivery system with its inherent limitations of individual time per student. Thus it is imperative that the instructional materials have tutorial or help features which stand in place of the teacher when the student is in trouble trying to understand a specific problem. These "help" or "tutorial" features should individualize to the problem the student is working on, and not just be a general tutorial discussing all problems of the type the student is working with. One of the reasons the development of excellent instructional courseware is so expensive is that the insertion of helps is not a simple task.

- The schools will also have to have the necessary number of instructional terminals connected to computers that can support the large programs required for serious instruction. Initially the number of terminals required will be at least 10 percent of the student body, but as time goes on, the figure will gradually rise to as much as 25 percent. Schools are very careless in recognizing how many terminals will be required before they can offer serious instruction with the new delivery system. A typical school of 600 students might have as many as 6 personal computers, and the school board might feel some justifiable pride at having provided them. Six terminals are adequate for modest efforts at literacy, but imagine if the school administration announced that in a school of 600 they had purchased 6 books to handle the student needs.

One of WICAT's clients, the Garland School District outside of Dallas, Texas, will be the first school district to hit critical mass in putting every student on a terminal for at least 20 minutes a day. Within a year or two, Garland will have at least 100 professional systems installed that will support 3,000 work stations. This will allow Garland's 33,000 students to be on the computer every day taking a full range of curriculum and testing programs. They are using many of the lessons learned by the Waterford School in their implementation strategy.

- A first rate authoring system will have to be available to allow schools to begin to develop some sub units of their own materials. An authoring system allows a faculty member or student to write instructional materials without knowing anything about programming. This is important because it allows a talented curriculum developer to avoid hiring legions of expensive programmers. One of the problems of developing instruction is that it is of necessity an iterative process. That is to say the materials must be changed constantly as students make comments on its effectiveness. If programmers are being used, the constant iteration and change compounds the expense and frustration dramatically; whereas, an authoring system allows the changes to be made quickly and inexpensively. Furthermore, the code is written error free by the authoring system so there is no expensive debugging time required.

  A good authoring system takes about five years and many millions of dollars to develop. The market is full of tiny inefficient authoring systems which claim to do the job effectively, but there are very few professional authoring systems because they require not only the initial investment and many years of development time, but also heavy ongoing expense from a team of from 6-12 people to maintain and improve it.

- An effective implementation strategy, including training procedures, must be developed. The actual educational delivery system of a school will be changed by the new technology, affecting the administration, faculty, students and parents. Training and implementation must take into account the changing needs of each of these constituencies.

- The use of administrative packages. Once a school has a powerful computer on site, the administration will want to use the potential of the machine for administrative purposes as well. Thus a full component of administrative programs will have to be developed that will help the school in such areas as:

  - scheduling of classes
  - keeping of student records
  - development of bus schedules
  - daily grade and attendance programs
  - use of word processing for the main office
  - use of financial modeling packages and spread sheets
  - payroll packages
  - financial records

- The development of a broad range of computer based testing programs will also have to be completed. These tests will cover the traditional topics and then some new areas as well:
  - district achievement tests
  - state achievement tests
  - national achievement tests
  - IQ tests
  - tests for learning disabilities such as dyslexia
  - the development of an individual learner profile
  - the development of talent oriented tests to pinpoint specific capabilities
  - tests for use with guidance counselors for vocational counseling

The Status of These Delivery System Requirements

1985 is probably the first year when a majority of the necessary conditions for the implementation of a new delivery system will be completed. For example, WICAT Systems has accomplished the following:

- By the end of 1985 the company will have spent close to $30 million on the development of courseware both for the large professional systems and personal computers.
- Each of the courses for the school market will have management and report packages that have been tested in various schools and modified according to faculty commentary.
- WICAT has a leadership role in developing its course materials with helps and tutorial features.
- After four years of development WICAT has completed a professional educational system which supports 30 users simultaneously with excellent audio at each work station. This system is also constructed to allow for a maximum use of graphics and animation to help clarify the instructional concepts.
- WICAT has developed the world's finest authoring system, called "WISE," which faculty members can use to develop their own materials. WICAT has spent many millions of dollars over five years on developing WISE. The program continues to be state of the art because WICAT has 8 people working on the program to improve it. Because WICAT uses the authoring system for its own courseware development, the company has a significant incentive to improve the product since any improvement saves the corporation development expense. As a result, the authoring saves the corporation development expense. As a result, the authoring system remains state of the art. Using the authoring system WICAT can produce its materials for approximately 30 percent of the cost of normal development and complete the product in half the time.
- The WICAT Education Institute has been working for 4 years to develop training and implementation strategies. As it works with the state of the art materials, the Waterford School is gradually evolving an ideal

plan for a school to follow for an implementation sequence. It also has recommendations for the best ways to train the faculty.

WICAT Systems offers training to its customers as part of its installation procedure, and also drawing on its experience with many sites in the field, can help a school get started with minimum confusion and maximum effectiveness. Obviously as the user community gets more sophisticated and the courseware continues to improve and schools continue to add more work stations, the training will evolve to new procedures, but the company will be able to offer appropriate training and implementation strategies for schools no matter what stage of development they have reached.

- The company has developed a full range of administrative programs with such areas as scheduling, attendance, student records and payroll and financial packages. There are also additional user packages such as word processing, etc.

- In testing, the WICAT Education Institute is doing a great deal of pioneering research in computer adaptive testing (CAT). Currently it holds a worldwide leadership position in this field. The Institute has received numerous grants from foundations to work on the development of the learner profile and has developed unique tools for computer adaptive testing development. Recently its Board of Trustees voted to accelerate its research efforts in this field and to make a major commitment to the testing area.

  WICAT Systems is just beginning to introduce its first testing as product to the school market. It is also working on collecting the various state requirements that are being developed by legislators for mandated curriculum objectives, and then these mandated objectives are being related to the current WICAT curriculum. This will allow states to prove that their students are mastering the objectives that have been mandated by the legislature.

The State of the Field in General

As we have seen above, WICAT is close to having completed most of the mandatory development requirements that the new delivery system will need if it is to be used effectively. Since the new delivery system simply will not be totally effective until all its components are fully working, a key question then is what is the status of the development of the field in general, as well as WICAT in particular. In order to clarify the discussion, we will separate the use of computers in schools into four different levels:

- Level I. Personal computers in a stand alone mode using floppy disks. Such machines as the Apple, IBM PC Jr, Commodore, Radio Shack, or Atari machines are typical members of this class. The acquisition and use of Level I hardware has some distinct advantages:

  - They can be purchased whenever surplus funds are available. Thus a district could buy a few through gifts from the Parent Teacher Association, individual donations, or when district or state

allocations are made for computers. This allows a school to gradually acquire a number of computers without any severe budgetary strain.

- They can be used very effectively in teaching computer literacy and computer programming.

- They are portable and can be moved about and get students and faculty introduced to computers with a minimum of fuss and strain. they cost from $500 to $2,000 apiece, which most schools can afford.

- Many of the larger computer companies are beginning to donate some of these to every school to get them involved in their particular brand.

Set against these advantages, there are some distinct disadvantages:

- Since the computers are not networked, the faculty are unable to follow what each student is really doing.

- Since the standalone terminals are being used primarily for programming and literacy courses, the training of the faculty is difficulty. Typically the faculty are trained in how to use a computer and the mechanics of programming and loading disks, etc. This leaves them feeling uneasy and tends to have them view the computer's contribution as primarily technical and extra-curricular.

- The development and usage of serious courseware for these Level I machines is difficult, and hence almost non-existent. The reason it is difficult is that a good course might require so many diskettes that it becomes very cumbersome for a complete useable inventory to become available to a student. Furthermore, the diskettes tend to wear out rather quickly under student handling and hence become a bit of an irritation as faculty try to is no longer functioning well.

- The hardware vendors and publishers of software for this level machine have tended to fool the unsophisticated schools into believing that there are thousands of excellent programs that have been developed for these machines. In fact there are many catalogs that list hundreds and hundreds of titles. Almost all of these titles have been developed by a single programmer trying to illustrate some point or piece of curriculum. A few are good, and most are bad. But in any case they do not add up to a cohesive curriculum. As the unsophisticated users begin to understand how limited the approach of Level I machines is for serious educational usage, they are beginning to move to Level II.

- Level II. Personal computers are no longer standalone, and they are connected to a disk file server.

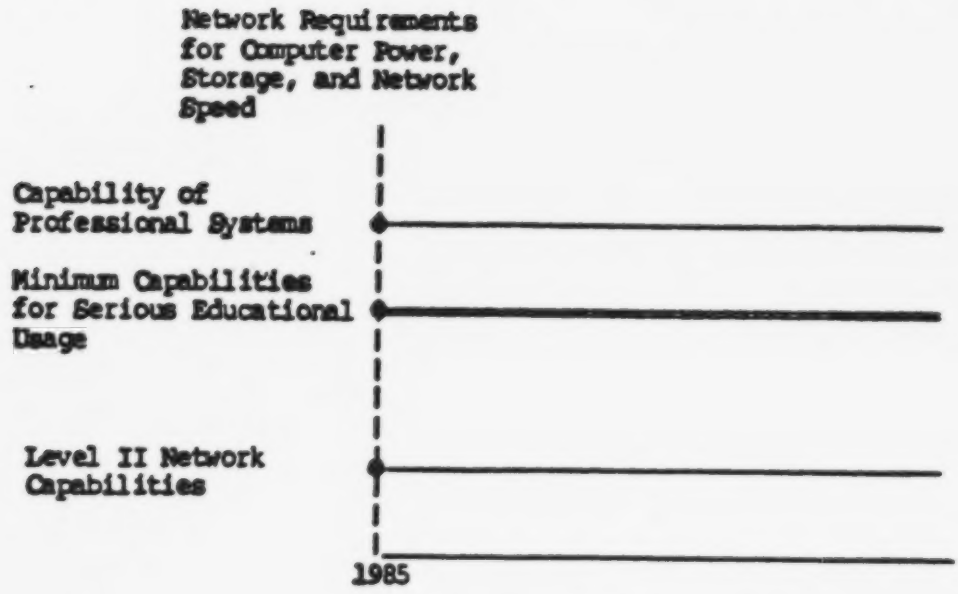
- In a marketing sense, 1985 will be the first year where many schools begin to go to Level II which is the linking of these micros into a network connected to a file server or hard disk drive. The entire field is moving towards a file server concept now that it is clear that the Level I machines have little serious instructional efficacy. There are some nice advantages of a file server system:

  - Faculty members can be relieved of handling multitudes of diskettes.
  - Records can be kept of student usage.
  - Larger programs and data bases can be stored to allow better programs to be used.
  - The networks can be put into computer centers that can be taken care of by paraprofessionals or aides, thus relieving the faculty member of the responsibility of handling and taking care of hardware.

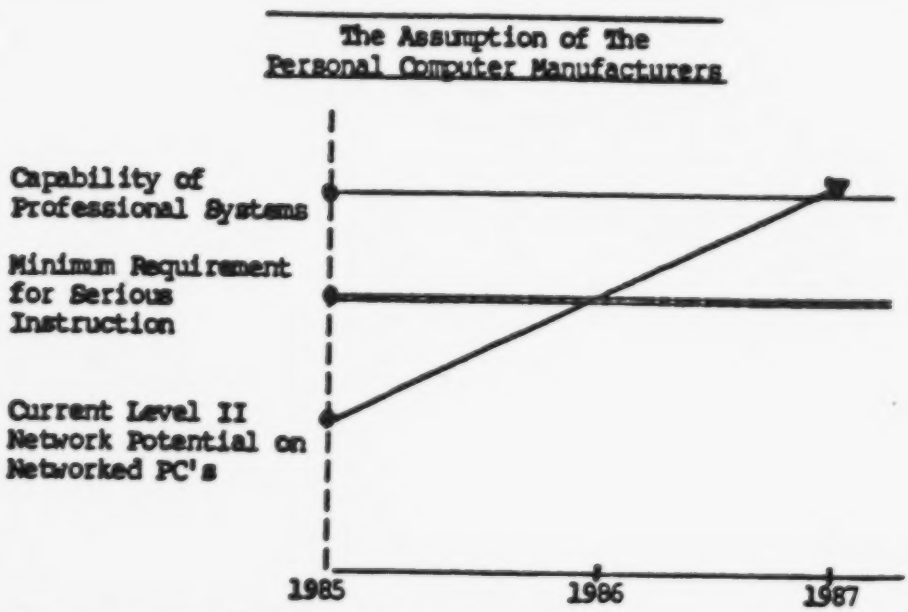
There are some serious disadvantages to Level II networks, however, that will probably preclude their being very effective instruments for serious educational usage.

- The primary problem is that these networks are market and not education driven. Recognizing that the standalone systems are not working, the hardware manufacturers are now selling schools on the new concept of networking. Thus instead of recognizing the inadequacy of the hardware design and addressing what hardware should be developed for serious educational usage, the companies are convincing the educational customer to following the path of least resistance. This fits the corporate needs, but not the educational needs.

- Specifically the networked micros will not have the technical power, speed, and storage capacities to handle the level of serious instructional potential that will be required to offer first rate instructional capabilities. The issue can best be illustrated in a diagram.

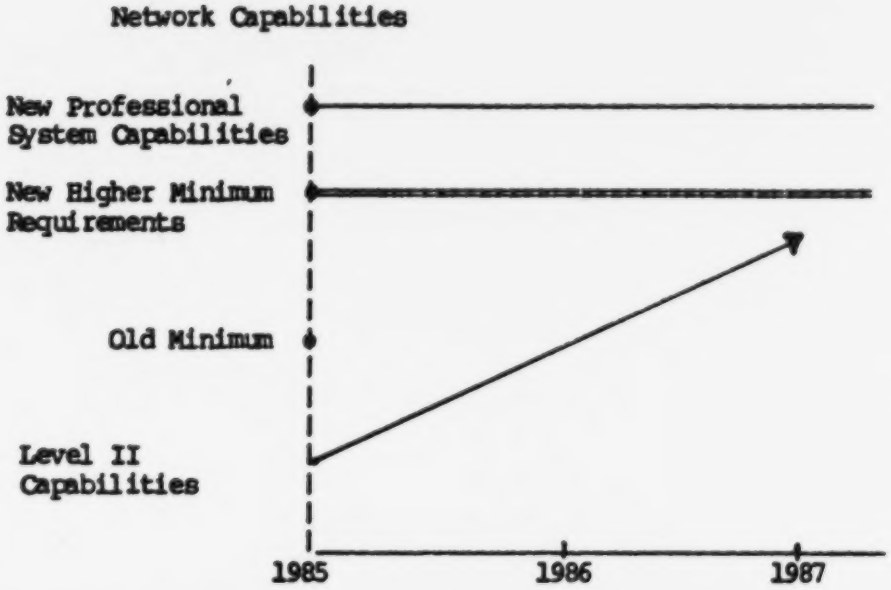

Network Requirements for Computer Power, Storage, and Network Speed
Capability of Professional Systems
Minimum Capabilities for Serious Educational Usage
Level II Network Capabilities
1985

The above graph illustrates that the network requirements that would allow enough computational power, storage, and program access speed are inadequate in 1985 to what minimum serious courseware requirements should be.



The above diagram illustrates the views of the computer manufacturers who are suggesting that the natural networking evolution will suit their customers some time in the next few years as the personal computer Level II networks will improve so that they can handle the storage, power, and transmission of large programs without difficulty.

What Is Really Happening



This diagram suggests that it is true that Level II network capabilities will continue to improve, but that based on WICAT's experience in the development of curriculum, the minimum accepted potential power storage and speed for serious educational software will continue to rise as well. In fact, the minimum accepted potential throughput will rise faster than the Level II networks will allow the materials to be transmitted. As knowledge is gained on how to make the curriculum more effective and changes are introduced, WICAT has found the program size requirements soaring faster than anticipated. A K-3 reading program in 1982 was 14 megabytes, and in 1984 it grew to 36 megabytes and in 1985 it will become 76 megabytes. The power of the Level II machines, the memory size, and the networking capabilities will not develop rapidly enough to handle this speed of change. Thus schools are embarking on a program which will leave them with networks that are partially useable but which will restrict them from having a serious educational impact on their students. At the same time the potential of the professional systems will continue to rise and stay well over the requirements of the courseware.

- A deeper problem is that even though the Level II networks will be able to handle better educational materials, there is a good probability that the software available for use on a Level II network will be Level I software. The reason for this is that software developers recognize that their educational software will not only be useful for schools, but, numerically more important for homes. The reason they are designed primarily for Level I or home usage is that there are 80 million homes and approximately 80,000 public schools. The order of magnitude difference assures that most of the software effort will assume parent purchase. There would be a significant additional expenditure if a company tried to modify Level I software

to use the full potential of the Level II network. Thus what automatically will happen is that Level I software will be put on a Level II network, but there is very little chance that true Level II software will be developed by most hardware or software vendors.

- In fact if one attends an educational conference in 1985 and views the sales personnel discussing the potential of the Level II network, there are really only three uses being discussed in a professional sense:
  - The use of the network for word processing as an aid to writing, etc.
  - The use of the network with financial spread sheets, somehow relating some of these spread sheet potentials to academic tasks.
  - The use of a data base on the hard disk to allow students to build various data bases and do research relating to the manipulation of the data bases. While these are useful auxiliary enterprises, they do not strike at the heart of educational need.

Level 3: The Professional System. The hallmark of the professional system is that it has more power and storage than a microcomputer network. The system design assumes that serious instruction will be the dominant use of the system, and hence it is designed to run very large educational programs and be used non-stop for the entire school day. The professional system can have excellent computer literacy courses on it, as well as courses in programming languages such as BASIC and PASCAL, but the professional system can best be used supplementing standard instruction for all courses. It is the first computer system that can offer the full advantages of the new delivery system, and hence if school districts have a desire to use their computers to improve instructional results, they should plan on introducing the professional systems as soon as possible.

The Level I and Level II personal computer applications will be excellent for computer literacy and teaching some computer programming and familiarity with the nature of a computer. They also will have some reasonable curriculum, but the quality of the instruction will necessarily be limited. The diagrams presented above suggested why they will have limits, but some concrete examples will help clarify the essential differences between a professional system and personal computers. The teaching of reading in a Kindergarten through 3rd grade setting is a major national task, so let us look at how each system will attack this problem. WICAT can discuss this with some expertise because it has spent a million dollars developing a reading course for the personal computer, and also a million dollars for developing a course on the professional system. First let us note how the personal computer handles the key developmental issues:

(1) The code used. The personal computer requires compact code because of storage limitations, and most developers are writing with BASIC, PASCAL, C, or FORTH. WICAT has chosen to write its programs in FORTH because it is the most compact of the higher level languages. As the program is developed, the various graphics and animation sequences as well as the curriculum filling the frames, and the audio, are all programmed by professional programmers using the FORTH language. The development of the reading program for the personal computer took WICAT over two years.

(2) Audio. The personal computer audio is limited to the number of words that can be stored in the auxiliary audio box. Words can be stored in two ways:

- by being permanently burned into chips,
- being placed on floppy disks.

Although the quality of the sound is improving so that it is starting to become natural, the size limitations of the audio storage restrict both the number of vocabulary words that can be used and the ability to put natural speech rhythms in phrases and words. As we talk we tend to change the sound of our words at the end of a sentence to accommodate the context of the sentence, and simply plugging all the words in sequence from storage to construct a sentence leaves the sentence sounding artificial and stilted. The way to improve this is to recall whole

phrases or sentences rather than constructing sentences from individual words. But here the personal computer storage limitations work against this goal.

(3) Graphics. Because graphics require an extraordinary amount of storage, they are used very sparingly in personal computer programs. Generally speaking, a single graphic is used as much as possible, and the program works through that graphic by changing modest portions of it during the interactive instruction. When WICAT finished its K-3 reading program, there were six key graphics used to frame most of the interactions with the student.

(4) Animation. Animation can be very useful in helping clarify concepts, providing motivational game sequences, and making the instructional material more interesting. Unfortunately, programs which animate the screen are very large and hence again are limited in a personal computer setting.

(5) Program size. The instructional programs have to be designed to fit some specific personal computer memory size. Some have to fit within a 64K memory, others into 128K memory. It is difficult to know what maximum size to make the programs because there is a serious tradeoff if the program size gets too large. The tradeoff is that many of the personal computers that would be in a school or home setting would not have enough memory in them to support a large program size. WICAT has chosen 128K as its program size which means that many of the earlier personal computers cannot use the programs, but most of the new ones can.

There are two problems in having this kind of restricted program size:

- The first is that only a certain amount of interaction can be generated with a memory of 128K before new information has to be brought in from the disk. As we have seen, this restricts the audio, graphics, and animation capabilities, as well as the general size of the instructional program.

- Perhaps more significantly there is a larger problem in that once the million dollars per program is spent over a 2-3 year development span, that program will be frozen for a considerable length of time in terms of its instructional potential. Companies cannot afford to change these programs lightly, nor to expand them easily because writing in a language like FORTH is very expensive, time consuming, and requires a long period of debugging to flush out the code errors.

(6) Instructional strategy. Because of the inherent limitations of points 1 through 5, inevitably the instructional strategy in a personal computer is also limited. Most of the interactions that a professional system can have are also replicable on a personal computer, but since the personal computer has so many limitations the student receives only a limited subset of the potential curriculum. In the reading course, for example, he is constantly recycled through six core graphics that give him excellent drill and practice, with limited audio and animation, but leaving him with only a fraction of what he might learn with a professional system.

Contrast these same items with a professional system:

(1) Code. A professional system uses an authoring system which allows the development of the materials to go forward without using programmers. This has significant advantages in that there are no code errors to debug because the authoring system writes a code automatically and accurately. This means on a dollar by dollar basis, much more development can take place with the developers concentrating on educational excellence rather than coding problems. Generally speaking, an authoring system can develop a superior product at 1/3 the cost in about half the time.

(2) Audio. A professional system such as WICAT has a separate subassembly of microprocessors to drive higher quality audio out through each terminal where the student uses earphones so as not to irritate his neighbor. Using the authoring system, the professional system allows the developers to input the audio through a microphone, and the professional system automatically digitizes the speech and stores it on a large disk. A minimum of a megabyte of memory is assigned for holding vocabulary words stored and downloaded from a large fast disk drive. This gives the program developer, and the students, an almost unlimited vocabulary with high quality audio. More importantly, it allows whole phrases and sentences to be recalled at fast speed so that the machine can hold a constantly natural sounding interactive dialogue with the student.

(3) The authoring system allows graphics to be developed very quickly, and because the professional system is built for larger storage requirements, many more graphics can be input into the system. For example instead of having the six key graphics that the personal computer version has in the K-3 reading program, the professional system has 12,000 graphics in its K-3 reading program. As we shall see, these graphics make a critical difference in helping a student improve his reading.

(4) Animation. The authoring system, the storage capability, and the speed of the system allow an almost unlimited use of animation with the graphics in the professional system. This is possible because the professional system has a special subset of microcomputer boards which control graphics and animation for every 5 terminals that are connected into the master host. These subsystems allow the use of almost unlimited graphics and animation because their separate processors can drive the 5 terminals without slowing the machine down.

(5) Program size. Instead of limiting the program size to 128,000 bytes of storage as is the case of the personal computers, the professional reading program size is measured in millions of bytes of storage. Currently WICAT will not ship a professional system with less than 160 million bytes of disk storage and 3 million bytes of main memory if a school intends to run a number of the programs. In the future WICAT will offer smaller systems which can specialize in subsets of the curriculum, but it should not be very many years before the program size requires disk drives of 474 millions of bytes of storage, and as development continues, it is not inconceivable that disk drives will require billions of bytes of storage for future professional systems.

For example, the first K-3 reading program was 14 megabytes, (millions of bytes) but after testing it in the field for two years, WICAT improved the program and it is now 36 megabytes. This statistic helps clarify the earlier diagram which indicated that the program size is increasing faster than the ability of networks to handle the transfer of data. But an ideal program for K-3 reading would even be larger because it would have to assume that a standard K-3 reading program would not be helpful for ESL students (English as a Second Language) who are increasingly flooding our schools. For example a majority of the incoming Kindergarten students in some of our southern cities are now Spanish speaking. Thus a first rate reading program would have to assume that some of the students in the class would be foreign speaking and should have a separate instructional sequence to fit their individual needs. In order to accomplish this, WICAT has, on the professional system, developed an English as a Second Language (ESL) program that has a separate audio, graphics and instructional component that can run concurrently with the normal K-3 reading program. In its first version this ESL program requires 40 megabytes, and no doubt it will expand in the future as it is field tested and improved. Even in the first version, however, the ESL and K-3 reading program running concurrently will require 76 megabytes of storage. As improvements take place this could swell to as much as 150 megabytes.

Since time is such a precious commodity in a school, and freeing up 20-30 minutes for a K-3 class to use the system on a daily basis is not a simple matter, it is important that when a class enters the center that there be appropriate materials for both the English speaking and ESL students in the section so as not to waste any of their time. Only then will the full capabilities of the system be realized.

(6) Instructional strategy. In order to understand the full implications of the improved instructional strategy that a professional delivery system offers, let us break down a particular reading task. Assume that the student has learned the alphabet and is now beginning to learn individual sounds such as the "at" sound. As part of an instructional sequence the child will learn that the "at" sound is found in such words as cat, bat, and rat. Here audio plays a critical role because the child already understands what a cat, bat, or rat is, so the problem is linking what the child understands to new symbols that he is learning. We forget that an illiterate child is really fully literate in the sense that he can understand audio and converse in a symbolic language verbally.

One goal in teaching the child to read well is to link these new symbols he is learning with the world he understands. One of the problems of a limited presentation, however, is that the student is unable to tell whether he is learning some new symbols that are unfamil- iar, or whether they relate to the world he understands. For example in learning the alphabet, the student has to understand that a "b" sound is different than the "bee" that might sting him even though they sound identical. In his mind he has to treat the "b" sound as a nonsensical item because he cannot relate it to anything he knows.

When a student is working with personal computer software restricted to six graphics and a minimal amount of audio vocabulary, he can be taught

to identify the words cat, bat, and rat as examples of the use of the "at" phrase, but he has no way of knowing that these words relate to the actual animals that he has heard of while growing up. In the absence of being able to be assured that cat, bat, and rat represent the real entities that he knows, he tends to treat these letters as a difficult exercise that he is mastering, but for all he knows they are nonsense phrases.

On the other hand, with a professional system, and the use of unlimited audio, animation, and with 12,000 graphics the student can learn that the cat word represents the cat that he knows in real life. This can be done by having the cat walk across the screen and make a sound like a cat. Thus a whole new instructional level is taking place where the student is learning vocabulary in context with the world he understands. Then because of the richness of the program size, the student can be given sentences using the words cat, bat, and rat where these words have pictures attached, and the student can even write sentences using the words, such as, "The cat bats the rat." Here even more learning takes place because pictures can act out what the student has written, so that literally a cat can bat a rat with its paw. The brighter students will pick up quickly that the word "bat" is now no longer a noun, but a verb as well. In other words, a professional system allows a far richer learning experience by placing the vocabulary in context with the world that the child already understands and helps him contextualize the phrases he is learning. By contrast, in using a personal computer curriculum, the student is apt to treat the words as nonsense phrases rather than see them in all their richness related to the world he understands.

There is another way that richness of the professional system increases learning in that it allows "context switching" to be a regular part of the instructional sequence. Context switching takes place when multiple presentations of a word are given in different contexts through using the full capabilities of the audio, graphics, and animation. Context switching is also enhanced through the sentence writing activity where the child becomes an active participant as he writes sentences that are then illustrated with graphics and animation on the screen. Research has shown that the context switching that comes from multiple presentations enhance both memory and meaning for the student.

Conversely, the limited presentation sequence available on a personal computer has some definite shortcomings including:

- Ultimately the restricted presentation will bore the student and damage both motivation and commitment, and hence learning.

- The absence of adequate graphics, animation, and audio, frequently distorts the student's perception of what the actual words and phrases mean because they present a blocking metaphor to the student concerning the full meaning of the word or phrase. In a sense, the restricted graphic acts as a mask which distorts and limits the student's perceptions.

Additional Contributions of a Level 3 System

In addition to the clear advantage in instructional gain that a professional system offers, there are also some new areas emerging that will contribute directly, and indirectly, to improving student performance that will require a Level 3 professional system as well. Some of these are:

(1) Computer Managed Instruction (CMI). One of the most important findings of The Waterford School in experimenting with computers and faculty attitudes is the significance of having outstanding CMI packages. These packages give the faculty members daily or weekly reports on the performance of their students using the computer-based materials. Good CMI requires not only the records of student performance in terms of the objectives of the lesson, but also a significant record data base so that a trace report can be pulled out on any student which reviews every problem and procedure the child has followed while working on the computer. Such a potential has some significant requirements:

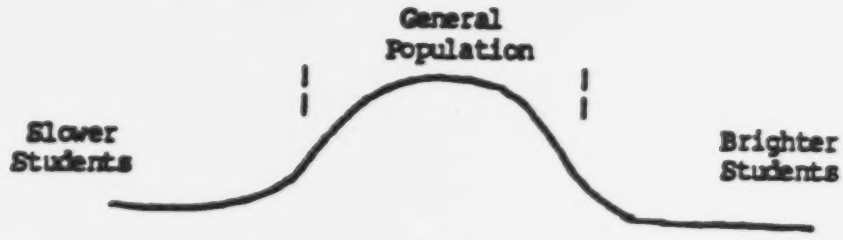
- The data base must be very large to allow the storage of these records. For this reason a large computer disk is required.
- The system must be powerful enough to sort through the various records and produce the required results quickly. This assumes, again, that the system is very fast and has the power of the professional system.
- The program size must be very large in order to make the most of the potential management information for the faculty member. Here again the program size would overwhelm the potential of a personal computer. If we assume that the management and testing capabilities of the new programs are opening an unseen world to the faculty member, and hence providing a new motivational tool, then to the degree the data is available, the faculty member will understand the implications and the value of the management system. While a personal computer can accomplish management, it has definite limitations. A good analogy might be to suggest that management system is like a microscope or telescope that can magnify an object by 5 times using the personal computer whereas it might be a thousand times using a professional system.

(2) Computer Adaptive Testing (CAT). CAT has some of the same attributes of CMI in that it reveals a hidden world of information, but it is a much more broadly-based technique to provide information about the student's general abilities, as well as his specific progress on the computer-based materials. The field of computer adaptive testing is in its infancy, but here again the image of the telescope or microscope is appropriate as a whole new foundation will be built in the testing area as computers aid us in understanding attributes about students that were previously invisible. This new knowledge will be extremely significant because under the current delivery system the amount of knowledge we can collect on a student is so primitive that it is only marginally useful. Because we frequently know so little about what a student is like as a learner and what his current state of knowledge is, much of the instruction that is given to a student is inappropriate.

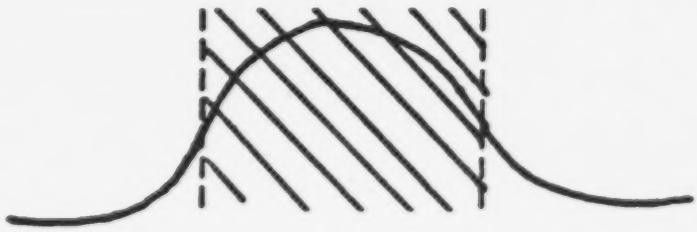
Now with the new knowledge that will be made available through computer adaptive testing we will be able to channel the teachers efforts in those individual areas where the student needs help, clarification, or encouragement. Thus the teacher will be far more productive because the computer testing will clarify whole new areas of information about the students' abilities and status that have been invisible, and this procedure will also then help the teacher individualize the instruction for each student as he works each day on the terminal.

There are a number of reasons that the use of CAT has signficant advantages over the normal testing procedures:

- The accuracy of the information collected on a student can be improved significantly. Most paper and pencil tests are designed to allow a user to take a series of items in a logical sequence in a specified length of time. The items tend to be simple in complexity and gradually increase until they are very difficult. Since the test is trying to discriminate what the student does and does not know, most of the items have to be designed on the assumption that the student is average or close to it. Since this is where the greatest percentage of students are this phenomenon can be shown graphically by the traditional bell-shaped curve.



Thus most of the test items will be near the top of the curve.



This inevitably leads to inadequate information on the slower or brighter students as shown below.

The key advantage of using computer adaptive techniques is that an intelligent testing program can branch quickly to different levels of difficulty and then begin to discriminate with great accuracy the student's specific ability. The student no longer is locked into a linear sequence of questions, but instead the intelligent testing program jumps whole sections of the test until it finds the student's approximate ability and begins careful discrimination testing. This approach is very helpful for a slow student, for example, because having quickly established that the student is not very strong it can generate many items which will help discriminate exactly what the weak student does and does not know. Obviously, the same holds true for the brighter students.

- The second great advantage of Computer Adaptive Testing is that the testing can be done in a fraction of the time, usually in less than half the time, with far greater accuracy. This increase in productivity follows because inappropriate test items are quickly screened out of the test sequence by the intelligent branching capabilities of the program.

- In addition to the significant increase in accuracy and saving of time, the third advantage is that the test results are available immediately after the completion of the test. Traditionally, test results are taken out of the school and shipped away for processing, and then the results are mailed back to the school weeks or months later. Obviously having the information available immediately will be very useful for helping placing students in appropriate classes, or once having been placed, helping the teacher understand that a student is having difficulties with particular concepts.

There will be many different uses of this new testing potential. Some of the obvious ones are:

- Schools will continue to offer the nationally normed tests in the Fall and the Spring, but now they will be able to have these tests take less time, give more accurate results, and produce immediate feedback to the school.

  Also there will be a new feature which allows the national tests to be available for the student to practice on during the year. At first, this ability to practice might appear to denigrate the value

of the test, but in fact the practice will simply become an additional learning experience while still retaining the validity of the test. Instead of having a fixed number of test items in a linear sequence that require great security, Computer Adaptive Tests will contain large data bases and thousands upon thousands of items that have been carefully validated. Thus when a student takes a test, he will have available many hundreds of items which represent the same degree of difficulty. Should he choose to practice until he can master the various items, he will not illegally have mastered the test items, but in fact have mastered the concepts that the test items are testing. Obviously if a student can work at the test over and over again, more learning will take place and the testing information will be more accurate.

- A second logical use of Computer Adaptive Tests will be the testing of specific state or district objectives. Many states are beginning to link state funding with proof that the school is teaching certain mandated curriculum objectives. Obviously the computer can be very helpful in not only accelerating the accuracy and speed of the testing, with its immediate feedback, but it also can generate explicit proof that the student either has passed the objectives, or that an individual educational program has been worked out for the student that will help him master the objectives.

- In addition to meeting national, state, and district test norms, the school will also use Computer Adaptive Testing as a test of basic skills which will enhance the placement of the students in appropriate sections or draw attention to deficiencies that can be remediated. Such tests can be extremely helpful as school opens, or even before school opens with new students, to allow the faculty and the school to understand exactly what the status of the students' mastery of the basic skills is.

- In addition to the improvement of traditional testing, there will be whole new areas of testing possible with the advent of Computer Adaptive Testing. Since the tests will be able to be provided much more quickly, schools will not hesitate to add new kinds of tests that have rarely been used because they have to be administered by trained psychologists. Since the professional system will have audio, graphics, and animation, many tests will be able to be administered without expensive psychologists. This will lead to a new democratization of testing which will insure that the poorest student has access to the type of testing that hithertofore has been restricted to a minority of wealthy parents who could afford these special tests. These tests can vary from identifying learning disabilities and dyslexia to discriminating what vocational talents the students might have. Perhaps the best generalization to explain what the new tests will encompass is the concept of a "Learner Profile" which will clarify for each student such things as:

    - The learner's potential for memory.
    - The learner's potential for originality.
    - Whether the learner is right or left brain dominant.

- What the learner's hidden talents are.
- What individual learning decay rate the learner has.
- What the learner's preference might be for career objectives.
- How the learner learns as a learner.
- What the learner's audio retention is.

In short, a Learner Profile will be developed on every student that opens a whole new world of information on how he learns as a learner and what his capabilities, interests, and deficiencies are.

There are some obvious concerns that follow from having this new kind of information available. For example, when the field of testing was established, a great deal of damage was done through the use of the IQ because people objected to having their apparent abilities relegated to a single number. We will have a similar problem as we learn to release the information of the Learner Profile to the faculty, the students, and the parents. We will have to invent a taxonomy or vocabulary that will not label children falsely or lead to misunderstandings because of careless phrases, metaphors, or comments. The Waterford School will be doing research in this area as it learns to release the information to various constituencies involved in the dissemination of the Learner Profile.

But despite the potential problem of releasing the information in a way that might falsely label a student, there is no question that the value of a well designed and carefully implemented program using the learner profile will be of inestimable value to students because it will offer them the most professional guidance in under- standing their capabilities, both for learning and work.

(3) Computer Adaptive Learning (CAL). Another reason that a Level 3 system will be required for the full potential of the new delivery system will be the gradual introduction of a new field called Computer Adaptive Learning. What this phrase suggests is that in a few years the computer programs that have identified an individual learner profile will then automatically begin to adapt the way the instructional materials are presented to the student to fit his individual learning style. Thus if a student were found to be right brain dominant and to learn best through seeing things graphically, the computer would be certain that a good percentage of the materials being presented to the student had graphic elements to enable him to learn the concepts more effectively. Gradually the first round of instructional programs that have been built will be amplified to include broader instructional examples and approaches that will allow a CAL program, using artificial intelligent techniques, to being to present materials to the student that are uniquely tailored to his talents and proclivities.

Obviously in order to have this capability, significantly larger curriculum packages will have to be built as well as programs that will be capable of interacting with the learner profile and the student. Practically what this means is that once again the computer programs will become even larger and require extraordinary storage capabilities in order to benefit the student to a maximum degree.

(4) Computer Based Administration (CBA). Obviously a school administration will receive a great deal of help with a professional system because its power and storage requirements allow it to handle all of the student records, scheduling, grades, attendance, and standard office functions such as word processing. But gradually as the various data bases are linked together including the CMI, CAT, and CAL, administrators will be able to extract information instantaneously on every student. Thus a superintendent on the telephone with a parent could call up on his terminal current information on that student. Furthermore, the computers could be taught administratively to look for changing patterns of student behavior to alert the faculty and administration to significant changes in student performance, attendance, or achievement. This information need not only be used negatively but also positively. Students who begin to perform more credibly can be positively reinforced from commentary from the administration as well as those who are drifting into difficulty. Problem areas can be noted rather quickly, but so can improvements.

Another area that will draw heavily on the administrative information, after all the components are linked, will be guidance. Obviously one of the by-products of sophisticated Computer Adaptive Testing is that information will be available about the students' hidden talents and interests that will enable the guidance counselor to give far more valuable information than normally would be available. By automating some of the standard psychological tests for talents and interests, the computer will have within it the equivalent of a collection of the world's great testing psychologists ready to offer information to each student through the guidance counselor, or even on occasion, his home room teacher. One of the added advantages of the new tests will be that they are not only pinpointing specific areas of competence that are frequently overlooked in a standard school setting, but they will also identify what the students' interests are. Sometimes there is a serious clash between what a student is good at and what he thinks he would like to do. In some cases, tests will show that students have an actual dislike for areas of talent and would like to pursue other areas where they have no talent. Obviously having objective data will give the student the maximum chance of not only working where he has talents, but also interests.

Summary: Currently, professional systems will be required not only to provide the finest instruction possible, but also many of the new supportive areas that will enhance the students' chance to succeed in his educational endeavors. Whole new areas of management, testing, adaptive learning and administrative counseling and information retrieval will also require millions and millions of bytes of storage and a powerful system that can handle all the necessary variables to see that these attributes are developed fully. School administrators, faculty members, and board members should understand that to the extent professional systems are not used, many of these potential advantages of the new delivery system will atrophy and be unavailable for their students and faculty.

Level IV

The use of computers at Level IV will take a few years to evolve because sophisticated administrative and communications packages will have to be developed to connect the professional systems together on a district, and ultimately, state level. As the professional systems provide the data bases of information on student performance and mastery, districts will want to be able to track how their students are doing, and in fact do research on what programs appear to be the most effective. This will require sophisticated communications capabilities between the professional systems and large mainframes that would be at district or state headquarters. The thrust in Level IV development will relate to communications and data base programming tasks.

Although there will be some resistance from schools and districts who will have reservations about their performance being tracked on an ongoing basis, clearly the pattern of legislators is to demand accountability from the school districts if they are to receive additional funding and support. Well developed district programs will enable the district to show not only the performance of every student, but also that they have been exposed to the state-mandated objectives, and where there are problems with students who are generally having learning problems, or who have dyslexia, or who fit in special student categories, the new networks will be able to help the districts specify the individual educational programs (IEP's) that are being developed for every type of student who is having learning difficulties. They will prove that their schools are meeting the mandated objectives and should help clarify where additional support is needed by the legislature where the school can show it has done a credible job at attempting to educate a student. Accountability can work in favor of schools as well as be constricting. Clearly if a school can show that a student has been exposed in a carefully programmed sequence to excellent curriculum on a regular basis, and indeed can run a trace on every trial with feedback that the student has undergone, it has far more credibility when requesting additional help for students who are not succeeding.

Level IV equipment will be large mainframe machines because they alone will have the power to take the input from all the professional school system data bases and manage the data for the requirements of the district or state. These will be significant programming tasks both in the communications and data base areas, but these are an inevitable step that will be taken some time in the future.

A Note on Cost

One of the responsibilities of school, district, and state educational leadership will be to understand and come to terms with the cost of giving the benefits of the new delivery system to their students.

Probably the best approach is to begin a planning and financial sequence which assumes that the new delivery systems can make a significant difference on the instructional quality of a school, district, or state. This means that studies will have to be made on the available curriculum as a starting point,

and then a great deal of research done on some of the new areas such as testing, computer management, and linking of state objectives to the curriculum, etc. Such a full study will inevitably lead a committee to the recognition that the school will have to use a professional system if it wants to have a serious instructional impact. Once the districts realize that professional systems will be required, they will have to initiate a funding and implementation sequence which will allow the schools to receive their systems in a logical and careful sequence. In order to gain the financial commitment required, the districts will have to keep their public constituency informed to raise the capital for the implementation sequence.

For example, the Garland School District in Texas experimented with a number of microprocessor laboratories and discovered that they ran through the useable curriculum in less than four weeks. This led them to an 18-month study which concluded they needed professional systems. While the study was going on, they passed a bond issue after educating their constituency for the need to spend $7 million to put in professional systems. Over a 2 1/2-year period Garland will be installing 100 of these systems that will be serving 33,000 students a day for approximately 20 minutes to half an hour. Garland is not a particularly wealthy school district, but because their planning was thorough and they kept the public informed, the public voted 6:1 in favor of the bond issues. Such a sequence takes time, careful planning, and educated leadership to implement.

The cost of introducing a professional system has a number of components:

(1) The cost of the hardware amortized over a 5 to 7-year span.

(2) Ongoing maintenance of the hardware.

(3) Leasing of the software so that the latest materials can be available each year to the students.

(4) The cost of a computer room aide or paraprofessional.

When all of these costs are taken into account, and assuming that a district wants to put its students on a professional system terminal for half an hour a day, then the cost per student should be in the $40 to $100 range per year. The figure varies according to how efficiently the computer is scheduled, what the salaries of the aides are, how large the discount is in the purchase of the hardware because of procurement size, and whether the district chooses to do its own maintenance or contract it out to a corporation. Assuming the cost per student for all instruction in a district is $2-$3,000, the cost for adding professional systems to a district can range from 1.5 percent of the district budget to as high as 5 percent. In most situations the annual cost would be somewhere between 2 and 3 percent of a district budget.

In unusual circumstances where a district can control the reallocation of personnel and would have the freedom to add one more student to each section, it is possible that the district would incur no additional cost on an ongoing basis. For example, the use of these systems will quickly

get rid of the need for a typing teacher because by the 5th or 6th grade these students will be averaging 40 words per minute from the typing program which is a portion of the overall writing program. If the typing teachers could be retrained and assigned as the aides, or if remedial teachers could be reassigned because of the remediation capabilities of the system, then personnel costs can be minimized.

Furthermore if the student costs for all instruction were say $2,500 for a given student, and the class size of the district was 24, and the district had the freedom to add one more student per section so that the class size was 25, even using the higher end of the cost estimate for technology ($100 per student), the ongoing use of the technology would not cost the district anything. The explanation for this is derived from the following assumptions:

(1) The cost of the computer instruction per year for a section of 25 students would be 25 students x $100 or a total of $2,500.

(2) But if a district could add a student to each section, the district would save $2,500 per section if the annual per pupil cost were $2,500.

(3) Thus adding a student to each section would save as much per section ($2,500) as the computer instruction would cost per section ($2,500). In this way if a district had the freedom to increase its section size by one student, it could have half an hour per day of computer instruction per student without spending any more on its annual budget.

There is a legitimate concern in adding a student per section because it increases the number of students that each teacher must work with, and hence it has an impact on the amount of individual instruction that each student can have with the teacher. But a strong argument can be made, as earlier sections of the paper have shown, that the computer's greatest contribution is that it gives each student exponentially more individual instruction, and hence far more value can be derived from having computer assisted instruction available than in having one student less per section.

Obsolescence as a Factor

Contrary to generally accepted perceptions in the computer field, there will be very few dramatic breakthroughs in the foreseeable future in hardware. In order to have something dramatic happen, there would have to be some new technological breakthrough which would significantly change the cost parameters. Such a breakthrough happened in the late 1970's when the microcomputer chip was invented which allowed a computer and an instruction set to be put on a single chip. Since in high volume the chip cost usually drops to the $2-$20 range, there was a tremendous advantage for micros in cost over many of our mainframe computers that had to be built thousands of electronic building blocks (chips) in order to develop the computer and its instruction set.

The cost, however, is no longer in the computer chip, and although more memory and power will gradually become available for the same dollar investment in an evolutionary sequence, the microcomptuer field will begin to slow down its development sequence and stabilize so that its software can be transmitted to the newer versions of the machines.

To use an analogy, the industry is in a situation similar to the automotive industry in the 1930's. Most of the players are clearly identified, the general design of the automobile has been completed, and although each year there will be some model changes, there will no longer be any dramatic changes that would obsolete the purchase of any model. As the models wear out, the consumer buys the newer version, but the consumer doesn't sense obsolescence as much as that the unit is wearing out. The same thing is true of the professional systems. As time goes on, the disk drives may get bigger, memory may expand more, or the tape drive may look different, but the major components which are in position will not obsolete. The software being developed for the professional systems already assumes enormous memory, storage, and power considerations, so as it is improved and added to over the years it will continue to run on both the old and new models of the machines, much as the way IBM has had its software compatible on its large machines ever since the advent of the 360 and 370. The current cost per work station for a professional system is approximately $2,500, and although the price may decline in the future, there is also the chance that it will remain constant as more memory and storage is added to the ever- expanding curriculum and testing requirements.

An Overview of Tomorrow's Schools

The WICAT Education Institute's work with its experimental school, The Waterford School, is beginning to clarify some of the uses of computers by tomorrow's educators in their schools. After four years of experimentation, Waterford has evolved into some of the following procedures:

(1) The school quickly learned that it is probably better both from a financial and a training support point of view to put the computers in a central setting in one room that can support at least 30 students simultaneously. One of the problems with scattering terminals throughout a building is that they will not be used nearly as efficiently as when they are placed in a laboratory where they are scheduled for 100 percent utilization during the day. Even a teacher with the best intentions that has two terminals in a classroom will not have those terminals in use all day because of recess, luncheon, and instructional activities. There will be times when the teacher will want to teach concepts to the whole class and not have two children working on the terminals while he is teaching a new concept. This means that for long periods of the day the two terminals will not be used, and hence the school's financial investment will not be used efficiently.

    Furthermore, if teachers are to have terminals in their rooms, they must receive a great deal of training on a continuing basis in order to be able to help the students to use these terminals properly. They also must face the inevitable maintenance problems that attend the use of diskettes

for the terminals. Finally, they may have to become programming experts because many of their students will want to use its computers to program. This places an incalculable burden on the teacher and the training of the teacher because he must understand the content of the computer curriculum, be able to maintain the system, and be able to help students who are involved with programming. Many teachers feel resentment at these demands, so it is probably best to put the computers in a center that can be used more efficiently and taken care of with less strain.

(2) The school also learned that an equally important step was to provide a teacher's aide or paraprofessional who is in the room with the system all day long. This paraprofessional schedules the use of the room with the individual faculty members and acts in a very important role as the interface between the teacher and curriculum. At Waterford, she has the nickname of "the computer lady," and her influence has made the installation a significant success. The value of such a paraprofessional is that she builds a relationship with the faculty members and helps train them and keep them up to date on the computer curriculum. The faculty member is relieved to have this constant resource. Together the faculty member and the paraprofessional bond and work with the students. Each day the paraprofessional meets with the homeroom teacher before classes begin and learns what instructional materials the teacher wants for her students. In this way the homeroom teacher can correlate her classroom activities with the computer. The paraprofessional can have all the materials ready as the teacher brings her students in, and then the teacher and the paraprofessional divide their efforts and work with individual students on the terminals. Sometimes they work with specific students that the management reports highlight as needing specific help, sometimes they work with brighter students who may deserve some individual time as well, and sometimes they respond to questions.

The paraprofessional has been trained on how to use the sophisticated managers that run the system. She need know nothing about computer programming, and by following some options outlined on the controlling console, the paraprofessional can quickly schedule all 30 terminals with the same curriculum or different curricula simultaneously at the request of the homeroom teacher. Thus the homeroom teacher never touches the computer and sees it only as an adjunct and support to her instructional activities. It is impossible to overestimate the significance of the relationship that is built between the paraprofessional and the homeroom teacher.

(3) Quite unexpectedly the use of the management programs to provide information to the teachers was the most important catalyst for faculty acceptance of the computer. One of the hallmarks of the professional system is that it has management curriculum and testing areas. One of the remarkable abilities of the computer is to track every instructional activity of the child and build solid research data bases on the students. As the faculty have become familiar with this potential, they have helped design management reports which bring them up to date on the performance of all their students in their class on every computer-based activity.

Here again the paraprofessional has a significant role because she runs the reports at specified intervals and then reviews the reports with the homeroom teacher. The metamorphosis of the homeroom teacher as she begins to understand the significance of the management reports is a remarkable phenomenon. Generally speaking, at first she is overwhelmed to find out how differently her students are performing on their various tasks. This detailed level of information has never been historically available before. Then within a few days she is comforted to see that indeed mastery is beginning to take place in the different objectives. Then new types of patterns begin to emerge that require intervention. For example, the computer will quickly highlight a student who is day-dreaming. One teacher discovered that her favorite and most apparently hard-working student was active only 59 seconds out of a 20-minute session. She watched the child look busy and active, while in reality she was simply daydreaming the day away. The teacher observed the same pattern in the classroom, and after a gentle intervention sequence with the student had her make a remarkable transformation in terms of being an active and alert learner.

Similarly, in many other cases, teachers will find students who work through a series of items very successfully until they are confronted with a question that forces them to demonstrate mastery of the core concept. At this point a certain type of student will then exit the program and start over with another sequence. A significant issue here is that the teacher will have to intervene to teach the student "risk taking" because obviously the student is afraid to try anything that might allow failure. Some of the more interesting successes at Waterford have been the renaissance of the students who have been taught risk taking and begin to explode with excitement at the realization that they discover that they really can use the concepts successfully.

In any case, these reports have a profound impact on the teacher in helping her to understand the potential of the computer. In fact one of the emotional highlights for the teacher is working with the latest management report with the paraprofessional and then mapping out the future scheduling of the machine to accommodate the findings. As the year progresses, the management reports have an additional feature which is very powerful that allows a faculty member to run a "trace" on any student. Most reports are given by class so that the teacher can measure performance of the individuals in the class, but a trace report is one that allows the faculty member to examine every interaction that the student has performed on the computer for the entire year. These trace reports frequently illuminate unusual patterns that help clarify the learning problem of the student.

(4) The Waterford experience suggests that the teacher training in using computers will probably evolve into a different approach than currently is being followed in most schools. At Waterford the teacher is trained to understand the curriculum and the testing and management potential of the system in relation to his classroom activities. He is not taught anything about the computer. When it is time for students to learn to

program, the class is turned over to the teacher who is an expert in programming. In general the training encompasses some of the following topics:

- The curriculum material available on the professional system.
- The nature of the management reports.
- The interpretation of these reports.
- How to work with the students in the computer room.
- How to relate the curriculum and management reports to homeroom teaching.

The training goes on continuously, and since it relates to subject matter primarily, the supervisors and the paraprofessionals work with the faculty members on an ongoing basis. Here the supervisor and paraprofessional play an important role.

These are some of the primary lessons that have been learned at Waterford that relate to the general introduction of the computers into schools. The more experimental research that is being done on the effectiveness of the various curriculum strategies or the accuracy of certain test procedures is being funneled back into curriculum and testing development.

The Potential for After School Use of the Professional System

Schools and districts will find out the presence of a professional system will lead to much more heavy use than they anticipate. In fact, this usage may lead to some income from the community using the machine beyond the normal school day. By simply hiring another paraprofessional for after school hours, at the very least the system could be used for significant tutoring capabilities for the weaker students. But what will probably happen in addition to this is that the families of the students or other adults in the community will begin to use the system as well. Within a few years the same diagnostic programs that are being used for children will be available for adults as well. Thus a parent could come in in the evening and take a sophisticated battery of tests that would help him understand his hidden talents and basic profile as a learner. For many adults this could be a serious benefit for retraining or job mobility. The tests will be able to offer an extraordinary range of valuable information for the adult. For example it might indicate that he could do well in a career in electronics, but also note that the learner's math skills need considerable enhancement. The same professional system will teach him the necessary math to pursue his electronics career. Further it is conceivable that within a few years WICAT will have developed additional curriculum in subject areas as electronics so that the adult would be able to be trained by the same delivery system until he has achieved significant proficiency in electronics.

For other adults who are having trouble surviving at a much more basic level because they cannot speak or read English, the English as a Second Language programs will be of great help, as will the writing program. The school could provide this service for very little cost because most of the programs are already on the system. As time passes, more and more programs will become available for the system until it will have the capability of becoming an

alternative educational center in its own right with only the addition of an inexpensive paraprofessional required to oversee its use. Inevitably these capabilities will extend the usage of the system to include weekends and summers as well as the evenings, and the cost of these additional activities will be measure in terms of pennies per hour. Thus the school will be left with the fortunate chore of deciding whether to make revenue on the extra curricular time, or whether to gain favorable community support by offering the services free, or at cost.

Under normal usage during the school year, a system would probably be used for between 1000 and 1200 hours during the school day. But if the system is scheduled for after school use, weekend use, and summer use, closing only for major holidays, there are an additional 3600 hours available for the community. In year round usage of the system, the school would be using the system less than 25 percent of the time! Thus the school will have a very valuable asset available if it chooses to use it fully.

The Importance of Time in a School Setting

Not enough has been understood about the importance of time in a school setting. The public, and even professional educators, tend to assume that most of the school day is spent in instructional activity. In fact, depending on the length of the school day, and the traditions of an individual school, the actual time spent in instruction averages only about 28 percent, or approximately 92 minutes a day. Of this 92 minutes, at best 1-2 minutes is individual instruction. These statistics are not to condemn the teacher, but to point out the realities of the time problem in the normal elementary school.

One of the most critical factors in trying to introduce computers successfully into schools will be their ability to capture time from the daily schedule to allow students to work on the terminals. While the average teacher is not conversant with the modest limits of the available instructional time, he intuitively understands that he needs as much time as possible with the students. Thus he is very reluctant to want to release them from his class to be turned over to a machine.

At the same time, however, clearly if a student could have up to 30 minutes a day of instructional time on the computer, and we assume that most of the time on the computer is spent in instructional interaction, and furthermore that this instructional interaction is individualized to the students' needs and forcing him into constant interactions where there are appropriate learning trials with feedback, then there would be a very dramatic increase in the amount of instructional time available in the average elementary school. In fact, there would probably be up to a 33 percent increase in general instructional time available, and up to almost 100 times more individual instruction available. As the paper points out elsewhere, the cost of this will probably be a general increase in the school budget of 2-4 percent, although it is possible, by either shifting personnel and/or adding a student per section, to eradicate any cost in an overall district budget.

Proponents of the computer will attempt to argue that the student should be on more than 30 minutes a day. The difficulty with this is that, as we have

seen, time is so precious to a teacher that while they collectively might be able to give up to 30 minutes a day to computer time, much more than this will start serious political consequences because of faculty resistance.

Opponents of the computer will argue that it is just an expensive fad that will not produce any demonstrable improvement for the students. When schools use professional systems, their chance of having the equipment make significant differences increases dramatically because they support programs and efficiencies that assure the proper use of available time. For example, WICAT learned that up to 40 percent of the available time on a personal computer can be wasted handling diskettes while loading curriculum with a standalone personal computer.

For the foreseeable future a school should run a middle course of action where it attempts to give a student somewhere between 20 and 30 minutes a day of instruction on the computer. Assuming the computer is a professional system, most or that time will be spent on individualized instruction. As we have seen in the above analysis, no other investment could come close to providing more instructional time on task. Over the next 5 years as the faculty, students, and parents begin to understand how useful this additional time is, they will begin to conceive of a renegotiation of the way the total time is used in a school day. At that point, faculty may be willing to give more time to a partnership with the computer, and school boards may be willing to give more capital to allow up to an hour and a half or 2 hours a day per student.

In summary there are two important issues to note here:

(1) School administrators and leaders should begin with an analysis of how much time a student will be allowed on a professional system because if they do not, they will not be focusing on a key issue of the use of instructional time in a school day.

(2) School boards and leaders should also come to terms with the fact that there is probably no other investment that can come close to the dramatic improvement in instructional time than the addition of professional computers. This 2-4 percent increase in a total school budget will far outweigh the advantages of any other expenditure of capital at this level.

A Note on Educational Software

A school district should not worry about whether or not there are multiple suppliers for software for their machines. What they should concentrate on is finding good software and then making their hardware decisions based on this. Some schools believe that personal computers should be purchased because there are many vendors offering software for this. At first this sounds somewhat convincing, but a close examination suggests the following problems:

(1) As we have seen, the personal computers are not the optimum machine to run educational software. Therefore the software is already somewhat limited in terms of educational effectiveness.

(2) The cost of developing software for personal computers is so high that various market organizations are trying to market just bits and pieces of small programs that they have developed. For this reason there are very few full courses available, and as a result school districts have to hire teams of people to constantly search through the bits and pieces to assemble a semi-coherent curriculum.

(3) Managers and reports get very confusing to the faculty if different reports are appended to different pieces of software. There is no coherence in the instructional reporting sequence that can help the faculty keep in touch with the student effort.

(4) Maintaining the software from different vendors becomes difficult, at best, because they have to be brought together in a way that is useable. When different software packages are merged, and problems surface, it is very difficult to find support from any single source.

Closer examination of the single vendor approach shows that a school is not restricted itself, but actually enhancing its percentages for success if it chooses a single vendor who has made a total commitment to the educational market:

(1) If the vendor has done a good job, his curriculum is much larger than the school can actually use in the time available to the students. There will be so many millions of megabytes of materials that the student will be able to branch and range through the curriculum for years at school and still have significant materials remaining.

(2) The vertical curriculum in each area will have a coherence that helps the student learn the materials in a logical and sequential fashion. There will not be conflicting educational theories represented with each new unrelated piece of curriculum that will confuse rather than clarify.

(3) All of the managers and reports will have a similarity that will help the faculty understand both the curriculum and status of the students without the confusion that would be generated by multiple types of managers representing different products.

(4) A single vendor who is concentrating on developing a coherent vertical curriculum package in a number of disciplines will continue to improve the materials each year and provide a single maintenance source when there are problems. Schools who have not used a great deal of computer hardware usually are unaware of the difficulty of trying to find out what is going wrong when the materials do not work. The hardware vendor will simply certify that his hardware works and the software vendor will certify that their materials work. Neither is prepared to work on the interface between the two materials to track the problems. On the other hand, when a single vendor is used, he has the responsibility of maintaining both, and as a result there is no conflict of interest when there are problems. And since the single vendor is responsible for both the hardware and software, they also have the knowledge to find the errors in the shortest possible time. Furthermore, if the vendor is committed to a total approach to education, he will gradually produce

superior materials because he will be constantly getting feedback from the districts as he takes care of his product and makes improvements. And in the case where the vendor controls his hardware design and can optimize it for educational purposes, the districts will find the greatest satisfaction. Obviously hardware that is designed for educational purposes will outperform hardware that has been designed for general purpose home and business markets.